PROTOCOL
FOR
URANIUM HOME SITE ASSESSMENT
GRANTS MINERAL BELT URANIUM PROJECT
CIBOLA AND McKINLEY COUNTIES, NEW MEXICO

Prepared for

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Appendix 1 Printout of the RESRAD Run Using Default Input Parameters

Appendix 2 Printout of the RESRAD Run Using Site-Specific Input Parameters

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHP	Certified Health Physicist
cpm	counts per minute
DCGL	Derived Concentration Guideline Level
DOD	Department of Defense
DOE	Department of Energy
EDE	Effective Dose Equivalent
EPA	U.S. Environmental Protection Agency
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
mrem/y	Millirem per year
μR/h	microRoentgens per hour
NaI	Sodium Iodide
NCRP	National Council on Radiological Protection
NMED	New Mexico Environment Department
NRC	Nuclear Regulatory Commission
OSC	On-Scene Coordinator
pCi/g	Picocuries Per Gram
pCi/L	Picocuries Per Liter
PIC	Pressurized Ionization Chamber
PRG	Preliminary Remediation Goal
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity modeling program
TEDE	Total Effective Dose Equivalent
UHSA	Uranium Home Site Assessment
UMTRCA	Uranium Mill Tailings Radiation Control Act

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) Region 6 Superfund Technical Assessment and Response Team (START-3) contractor, Weston Solutions, Inc. (WESTON®), was tasked by EPA Region 6 Prevention and Response Branch (EPA-PRB) under Contract Number EP-W-06-042, TDD No. TO-0005-09-02-01 to conduct assessments at residences impacted by uranium mining and milling operations in the San Mateo Creek Basin portion of the Grants Mineral Belt, which includes the Ambrosia Lake, Laguna, and Marquez mining sub-districts located in Cibola and McKinley Counties, New Mexico. START-3 was specifically tasked to develop a protocol for the assessment of radioactive contamination at residences using existing radiation guidelines, risk analysis procedures, and exposure models.

The San Mateo Creek Basin portion of the Grants Mineral Belt is located in Cibola and McKinley counties in northwestern New Mexico, near the town of Grants. This area was the site of extensive uranium mining from 1950 until the early 1980s. During this time the economy of the region changed from agriculture to uranium mining and uranium ore processing. Most uranium mining activities stopped in the recession of 1982-1983.

1.1 PROJECT OBJECTIVES

In 2007, EPA Region 9 began a project in coordination with the Navajo Nation to investigate residences on the Navajo Indian Reservation located in parts of Arizona, New Mexico and Utah for radioactive contamination caused by the legacy of uranium mining on the reservation. In 2009, EPA Region 6 initiated a similar project to investigate radioactive contamination in residences near uranium mining and ore processing areas outside of the Navajo Reservation in the San Mateo Creek Basin area of northwestern New Mexico. These areas will include non-Navajo lands adjacent to the eastern boundary of the Navajo Reservation with public and/or private ownership, privately-owned lands, and lands owned by the Laguna and Acoma Pueblos. This document outlines an approach for this investigation, using established EPA guidelines and documents.

The purpose of this document is to develop a survey protocol using the best available science in order to identify residences and related structures where a Removal Action should be performed to eliminate or greatly reduce the threat to the general public health and/or the environment posed by the legacy radiological contamination present on the Site, and to provide sufficient characterization data to allow for planning and cost estimating the removal. The protocol has been designed to maximize the use of field or in-situ data, and to minimize the use of sampling which requires the reliance on laboratory analysis. However, certain determinations such as radon sampling are more efficiently performed with laboratory support; therefore laboratory analysis will be utilized when it is determined to be more advantageous to the project. This document details the development of a protocol for the assessment of radioactive contamination at residences using existing radiation guidelines, risk analysis procedures, and exposure models. Details regarding the assessment procedures including specific instruments, sample analysis, and documentation will be developed and discussed in a separate Quality Assurance Sampling Plan (QASP) document.

2. IDENTIFY GUIDANCE DOCUMENTS

2.1 MARSSIM - PRIMARY GUIDANCE DOCUMENT

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) will be utilized to develop the radiation survey protocol (NRC, 2002). This document was prepared collaboratively by four Federal agencies having authority and control over radioactive materials: Environmental Protection Agency (EPA), Nuclear Regulatory Commission (NRC), Department of Energy (DOE), and Department of Defense (DOD). The MARSSIM, published in 2000, provides a nationally consistent consensus approach to conducting radiation surveys and investigations at potentially contaminated sites. In addition to planning, conducting, and assessing radiological surveys of surface soils and building surfaces, the document provides a decision-making process to determine if site conditions are in compliance with dose-based or risk-based regulatory criteria. As illustrated in Figure 1, the demonstration of compliance with respect to conducting surveys is comprised of three interrelated parts.

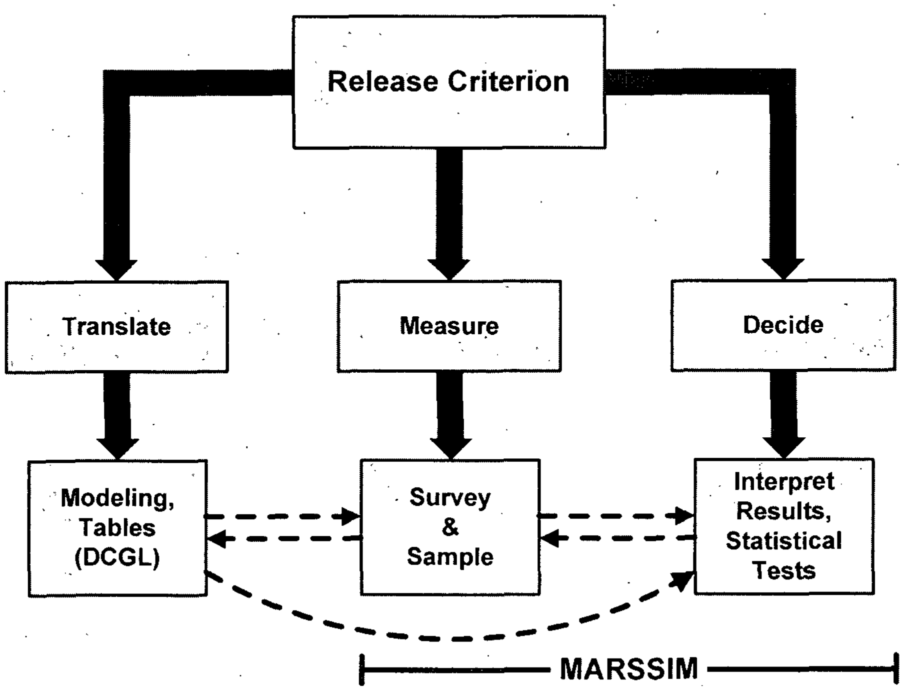

Figure 1
Compliance Demonstration

Translate: Translating the release or cleanup criterion into a corresponding derived concentration guideline level (DCGL) using pathway modeling. This task is not within the scope of MARSSIM.

Measure: Acquiring scientifically defensible site-specific data on the levels and distribution of contamination by employing suitable field or laboratory measurement techniques.

Decide: Determining that the data obtained from sampling does support the assertion that the site meets the release criterion, within an acceptable degree of uncertainty, through application of a statistically based decision rule.

Note that development or calculation of cleanup criterion or DCGLs is not within the scope of MARSSIM. The evaluation of surface water, groundwater, air particulates, radon, radon progeny, or gamma exposure rates is also not within the scope of MARSSIM. The contribution to the overall dose equivalent or risk from these environmental pathways is addressed in the derivation of the DCGLs.

2.2 MARSSIM VERSUS THE CERCLA REMOVAL PROCESS

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Removal Process defined in 40 Code of Federal Regulations (CFR) 300.415 (NCP subpart E- Hazardous substance Response) establishes methods and criteria for determining the extent of response when there is a release into the environment of a hazardous substance or any pollutant that may represent an imminent and substantial danger to the public health or welfare. The survey designs and statistic tests for relatively uniform distributions of radioactivity discussed in MARSSIM are also discussed in CERCLA guidelines. However, MARSSIM includes scanning for radioactive materials, which is not discussed in the more general CERCLA guidelines. MARSSIM is not intended to replace or conflict with existing CERCLA guidelines, but is intended to provide supplemental guidance for specific situations involving radioactive contamination.

The Removal Process is generally composed of four distinct steps: 1) Site referral; 2) Preliminary Removal Assessment; 3) Extent of Contamination; and 4) Removal Action. The scope of this protocol, here in after referred to as the Uranium Home Site Assessment (UHSA) will address the removal process steps 2 and 3, as referenced above. The UHSA protocol has been designed to be conducted in two phases in order to be consistent with EPA removal action policy and general consistency with MARSSIM protocols. The Preliminary Removal Assessment which is equivalent to the MARSSIM Scoping Survey will be conducted on all home site areas within the defined area of interest. If elevated radiological contamination is detected at a home site, the UHSA protocol will transition to the Extent of Contamination, which is the equivalent of a MARSSIM Characterization Survey to define the levels and extent of radiological contamination to allow for planning the Removal Action. Alternatively, if a Removal Action is not warranted, data from the UHSA will be referred to EPA Remedial Program and the New Mexico Environmental Department (NMED) for any further actions deemed necessary.

3. PRELIMINARY REMOVAL ASSESSMENT

The following is a detailed discussion of the science and assumptions made in association with the development of the procedures for the Preliminary Removal Assessment. As previously stated, the UHSA protocol calls for the implementation of these procedures on all home sites within the defined area of interest and is equivalent to the MARSSIM Scoping Survey.

3.1 DEFINE THE RADIOLOGICAL CRITERION

3.1.1 Risk

The Preliminary Remediation Goal (PRG) for Ra-226 is 0.0124 picocuries per gram (pCi/g), which represents a risk of $1x10^{-6}$ (EPA 1997, OSWER 9200.4-18). Since this concentration is below the analytical detection limit of 0.1 pCi/g for this radionuclide, EPA policy states that a $1x10^{-4}$ risk is protective as a removal action objective.

Additionally, according to EPA guidelines, 15 millirem per year (mrem/y) Total Effective Dose Equivalent (TEDE) represents an excess cancer risk of $3x10^{-4}$, and is considered essentially equivalent to the presumptively protective level of $1x10^{-4}$ (EPA 1997, OSWER 9200.4-18). TEDE is the sum of the dose received from external sources and the committed dose from internal exposures. The risk calculation in this case utilizes a 30-year exposure period per lifetime and a 24-hour/day exposure rate. The risk calculation is based upon a risk conversion factor of 7% cancer incidence per 100,000 mrem of TEDE and comes from Biological Effects of Ionizing Radiation Report V (BEIR V 1990). For the purposes of this UHSA protocol, the primary criterion will be a dose of 15 mrem/y (TEDE), which represents a cancer risk of $3x10^{-4}$.

3.1.2 Calculate $DCGL_W$

The DCGL is a radionuclide-specific soil concentration or building surface area concentration that would result in a TEDE equal to the release criterion. Exposure pathway modeling is used to calculate these concentrations. Exposure pathway modeling is the analysis of various exposure pathways and scenarios used to convert concentration into dose. The summation of all doses from all potential pathways is the TEDE.

A number of input variables can significantly affect the calculated result of pathway modeling. These variables include the depth of contamination, residency time, inhalation rates, air particulate re-suspension rates, and percentage of foodstuffs grown locally. Probably the most significant variable impacting the calculation of the DCGL is the modeled area of contamination. Due to the impact that these input parameters have on the results of the program output, they should be selected by a qualified and experienced individual such as a Certified Health Physicist (CHP). If the radioactivity is relatively evenly distributed over a large area, MARSSIM looks at the average concentration over the entire area. This is termed the $DCGL_w$. ($DCGL_w$ stands for DCGL-Wilcoxon, referring to the Wilcoxon statistical test). Concentrations above the $DCGL_w$ are allowed provided that they are of small enough area such that the average concentration over the survey area is still less than the $DCGL_w$. The MARSSIM approach allows for calculation of a higher DCGL Elevated Measurement Comparison ($DCGL_{emc}$) for small areas based upon "area weighting factors." This approach accounts for the fact that the resident will receive a smaller dose from a smaller area of contaminated soil. The $DCGL_{emc}$ is discussed in further detail in Section 3.1.5.

It is important to understand and to restate, $DCGL_w$ and $DCGL_{emc}$ apply only to soil or building surface concentrations. They do not apply to radionuclide concentrations in air particulates, radon, radon progeny, ground water, surface water, food stuffs, or gamma exposure rate. The dose contributions from these potential pathways are calculated from the soil or building surface concentrations by pathway modeling. It is assumed that the radioactive contamination is normally distributed.

This protocol uses RESRAD software to calculate TEDE from soil radionuclide concentrations, although many other programs are available (ANL/EAD, 2001). The RESidaul RADioactivity code was developed by Argonne National Laboratory for the U.S. Department of Energy, and calculates the Effective Dose Equivalent (EDE) from each radionuclide though each pathway. The six pathways evaluated in this protocol development include direct exposure, inhalation of air particulates, and ingestion of plant foods, meat, milk, and soil. Default values are provided for parameters used by the code. Different exposure scenarios can be specified by adding or suppressing pathways and modifying usage or occupancy factors. RESRAD essentially mimics a classic Site Conceptual Model, taking into account all pathways of exposure.

Table 2 summarizes the RESRAD-calculated EDE from all pathways for a UHSA, assuming the standard default values assumed in RESRAD, and assuming an average soil concentration of 1 pCi/g for U-238, U-234, Th-230, Ra-226, Po-210, Pb-210, and all associated progeny in equilibrium. The calculated TEDE to the resident using these assumed input parameters is 17.15 mrem/y. Given that the primary cleanup criterion is 15 mrem/y TEDE, the $DCGL_W$ calculates to approximately 0.9 pCi/g.

Important to note is that the critical radioisotopes to the TEDE in this scenario are Ra-226, contributing approximately 66% of the total dose equivalent, and Pb-210 contributing approximately 31% of the total dose equivalent. All other radioisotopes combined contribute only about 3% to the total dose. Also of note, the critical pathways for these isotopes appear to be the ingestion of plant crops, which contributes approximately 57% of the total dose equivalent, and direct exposure to contaminated ground surface which contributes approximately 37% of the total dose. The other pathways evaluated contribute only approximately 6% to the total dose. A conclusion that can be drawn from this is that the contribution to the total dose from U-238, U-234, and Th-230 is relatively negligible; therefore, the dose impact from either uranium mine waste rock or mill tailings, which have had the uranium extracted, would be substantially equivalent.

As stated previously, changing input parameters can significantly impact the calculated doses. Default values imbedded within RESRAD are generally considered conservative but reasonable input values for the average person within the U.S. However, site-specific parameters can be input into RESRAD which are unique to the local area if these parameters can be identified. A series of RESRAD analyses were performed to identify the more sensitive parameters which affect the calculated result in this scenario. A list of selected input parameters for the generic and site-specific RESRAD analyses is presented as Table 1.

Table 3 provides the calculated EDE from 1 pCi/g of the above radioisotopes assuming the site-specific input variables. The calculated TEDE using these site-specific parameters is 5.9 mrem/y. Given that the primary cleanup criterion is 15 mrem/y TEDE, the $DCGL_W$ calculates to approximately 2.5 pCi/g.

From this data, it can be discerned that the critical radioisotope in the site-specific scenario is Ra-226 which contributes approximately 92% of the TEDE, and the only significant pathway is direct exposure to the soil surface which contributes approximately 92% of the TEDE. To quantify the dose increase due to U-235, which was not considered in the prior RESRAD analyses, the RESRAD calculation was repeated with the uranium-235 chain added. The overall effect was that the TEDE increased from 5.9 to 6.0 mrem. The scenario used was the same in every respect as the one that produced the result presented in Table 3. The marginal dose increase for this scenario further supports the claim that Ra-226 is the critical isotope.

During the assessment work, when a residence is found to have conditions that differ significantly from the assumptions made during the calculation of the $DCGL_W$, the RESRAD model will be run with site-specific parameters to determine a $DCGL_W$ for that residence. In particular, the presence of a vegetable garden in a residential yard could have a large impact on the $DCGL_W$, and the RESRAD model would be run with vegetable consumption information for that particular residence.

A printout of the RESRAD model run using default input parameters is included as Appendix 1. A printout of the RESRAD model run using input parameters specific to the San Mateo Basin is included as Appendix 2.

3.1.3 Identify Critical Pathways

From data in Tables 1 and 2, it is concluded that the critical isotope of concern is Ra-226, and the critical pathway, assuming the site-specific parameters, is the direct exposure to contaminated soil. All other radioisotopes and all other pathways contribute less than 8% to the TEDE. It is also concluded that the $DCGL_W$ for this UHSA will be 2.5 pCi/g of Ra-226 in surface soil. Therefore, Ra-226 is the critical radioisotope that needs to be sampled or measured, and direct exposure is the critical pathway.

3.1.4 Compare DCGLs to Other Published Release Criteria

The $DCGL_W$ can be compared to relevant EPA, NRC, and NCRP criteria for the radioisotope identified as being critical in Section 2.3. These relevant criteria include:

- EPA Site Screening Levels
  - Ra-226 at 0.41 pCi/g above background assuming a risk of 1×10^{-4}
- EPA Preliminary Remediation Goals (EPA 1997, OSWER 9200.4-18)
  - Ra-226 at 1.2 pCi/g above background for residential soil and 0.06 pCi/g above background for agricultural soil both assuming a 1×10^{-4} risk
- EPA UMTRCA standards, 40CFR192
  - Ra-226 in surface soil at 5 pCi/g, above background.
  - Ra-226 in soil below 15 cm at 15 pCi/g above background.
- NRC/NUREG 1757 surface soil screening levels (NRC, 2006)
  - Ra-226 in soil at 0.7 pCi/g above background
- National Council on Radiological Protection (NCRP) Report 129 (NCRP, 1999)
  - Ra-226 in soil in a rural, sparsely vegetated area at 0.1 pCi/g

The State of New Mexico has no regulations that are directly applicable to radioactive contamination in residential soils.

Table 1
Selected Input Parameters for RESRAD Analyses

Parameter	Default Value	Site-Specific Value
Thickness of contaminated soil	2 meters (~ 6 feet)	15 centimeters (~ 6 inches)
Area of yard .	10,000 m^2 (~ 2.5 acres)	4,000 m^2 (~ 1 acre)
Home-grown fruits, vegetables, and grain consumed annually	160 kilograms (~ 350 pounds)	2 kilograms (~4.4 pounds)
Home-grown leafy vegetables consumed annually	14 kilograms (~ 31 pounds)	2 kilograms (~4.4 pounds)

Table 2
Uranium Chain Total Dose from RESRAD Output Using Default Values

Radio-nuclide	Ground		Inhalation		Plant		Meat		Milk		Soil		TEDE[3]
	mrem/yr[1]	fract.[2]	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	
Pb-210	3.445E-03	0.0002	1.189E-03	0.0001	4.769E+00	0.2781	2.670E-01	0.0156	8.798E-02	0.0051	1.725E-01	0.0101	
Po-210	1.345E-05	0.0000	2.744E-04	0.0000	7.556E-02	0.0044	7.766E-02	0.0045	7.530E-03	0.0004	2.373E-02	0.0014	
Ra-226	6.304E+00	0.3676	5.666E-04	0.0000	4.678E+00	0.2728	1.393E-01	0.0081	1.657E-01	0.0097	3.870E-02	0.0023	
Th-230	2.062E-03	0.0001	2.086E-02	0.0012	4.868E-02	0.0028	1.003E-03	0.0001	9.967E-05	0.0000	1.501E-02	0.0009	
U-234	2.320E-04	0.0000	8.433E-03	0.0005	6.149E-02	0.0036	2.029E-03	0.0001	4.974E-03	0.0003	7.734E-03	0.0005	
U-238	8.572E-02	0.0050	7.541E-03	0.0004	5.838E-02	0.0034	1.926E-03	0.0001	4.722E-03	0.0003	7.344E-03	0.0004	
Total	6.395E+00	0.3729	3.887E-02	0.0023	9.691E+00	0.5651	4.890E-01	0.0285	2.710E-01	0.0158	2.650E-01	0.0155	17.15

1 - Maximum dose rate (mrem/yr) occurs at time=0 for a 1000 year assessment.
2 – Fract. = The fraction of the TEDE contributed by a specific radioisotope through a specific pathway.
3 – TEDE = Total Effective Dose Equivalent.

Table 3
Uranium Chain Total Dose from RESRAD Output Using Site-Specific Values

Radio-nuclide	Ground		Inhalation		Plant		Meat		Milk		Soil		TEDE[3]
	mrem/yr[1]	fract.[2]	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	
Pb-210	3.330E-03	0.0006	1.054E-03	0.0002	1.792E-02	0.0030	6.134E-02	0.0104	2.026E-02	0.0034	1.689E-01	0.0285	
Po-210	1.130E-05	0.0000	2.323E-04	0.0000	2.737E-04	0.0000	2.623E-02	0.0044	2.573E-03	0.0004	2.208E-02	0.0037	
Ra-226	5.358E+00	0.9046	5.062E-04	0.0001	1.760E-02	0.0030	1.657E-02	0.0028	2.104E-02	0.0036	3.799E-02	0.0064	
Th-230	1.851E-03	0.0003	1.892E-02	0.0032	1.884E-04	0.0000	3.551E-04	0.0001	2.973E-05	0.0000	1.496E-02	0.0025	
U-234	2.251E-04	0.0000	7.494E-03	0.0013	2.315E-04	0.0000	6.265E-04	0.0001	1.594E-03	0.0003	7.553E-03	0.0013	
U-238	7.693E-02	0.0130	6.702E-03	0.0011	2.198E-04	0.0000	5.949E-04	0.0001	1.514E-03	0.0003	7.172E-03	0.0012	
Total	5.440E+00	0.9185	3.491E-02	0.0059	3.644E-02	0.0062	1.057E-01	0.0178	4.701E-02	0.0079	2.587E-01	0.0437	5.923

1 - Maximum dose rate (mrem/yr) occurs at time=0 for a 1000 year assessment.
2 – Fract. = The fraction of the TEDE contributed by a specific radioisotope through a specific pathway.
3 – TEDE = Total Effective Dose Equivalent.

3.1.5 Calculate $DCGL_{emc}$

As stated previously, the $DCGL_W$ is based on the average soil concentration across the survey unit using exposure pathway models which assume a relatively uniform concentration of contamination. While this represents the ideal situation, small areas of elevated activity are also of concern. Scanning surveys are used to identify these small areas of elevated activity. The criterion to which elevated small areas of contamination are compared is the DCGL Elevated Measurement Comparison, or $DCGL_{emc}$. The $DCGL_{emc}$ is calculated by modifying the $DCGL_W$ using a correction factor that accounts for the difference in area and the resulting change in dose or risk. The area factor is the magnitude by which the concentration within the small area of elevated activity can exceed the $DCGL_W$ while maintaining compliance with the release criterion.

Tables 4 and 5 provide examples of outdoor and indoor area dose factors for Ra-226. If the $DCGL_W$ is multiplied by the appropriate area factor, the resulting concentration distributed over the specified smaller area delivers the same calculated dose. For example, since the $DCGL_W$ for Ra-226 is 2.5 pCi/g (as described in Section 2.2 above) if the elevated concentration detected by scanning has an area of 3 m^2, the $DCGL_{emc}$ would be 2.5 pCi/g times 21.3 or approximately 53 pCi/g.

If multiple elevated areas of contamination are found with multiple radionuclides in addition to a low level of residual radioactivity distributed across the survey unit, the unity rule must be used to ensure that the total dose or risk meets the release criterion.

Table 4
Outdoor Area Dose Factor[1]

Outdoor Area Factor for Radium-226[2]									
Area Size	1m^2	3 m^2	10 m^2	30 m^2	100 m^2	300 m^2	1,000 m^2	3,000 m^2	10,000 m^2
Factor	54.8	21.3	7.8	3.2	1.1	1.1	1.0	1.0	1.0

1 – Taken from MARSSIM, Table 5.6 (NRC, 2002)
2 - The area factor is the magnitude by which the concentration within the small area of elevated activity (hot spot) can exceed the DCGLw while maintaining compliance with the release criterion.

Table 5
Indoor Area Dose Factor[1]

Indoor Area Factor for Radium-226[2]						
Area Size	$1m^2$	$4m^2$	$9m^2$	$16m^2$	$25m^2$	$36m^2$
Factor	18.1	5.5	2.9	1.9	1.3	1.0

1 – Taken from MARSSIM, Table 5.7 (NRC, 2002)
2 - The area factor is the magnitude by which the concentration within the small area of elevated activity (hot spot) can exceed the DCGLw while maintaining compliance with the release criterion.

3.2 DEFINE REFERENCE AREA (BACKGROUND)

Areas which have no reasonable potential for residual contamination are classified as non-impacted areas. A reference area is selected essentially as a background against which readings at residential sites can be compared. The reference area is a non-impacted area representative of the UHSA grouping with similar physical, biological, chemical, and radiological characteristics. Selection is made by gamma radiation level, geological formation, and home-site construction material. Reference area data will be collected for environmental media identified for the critical radioisotopes and critical pathways identified in Section 2.3. For the UHSA protocol, this will require collection of soil samples analyzed for Ra-226, and stationary 1-minute count rate readings above each sample/ measurement location. For sound statistical modeling, a minimum of 20 samples or measurements will be collected for each critical media.

3.3 DEFINE STATISTICAL TEST

Since all of the radioisotopes of concern are also present in the reference area, the Wilcoxon Rank Sum (WRS) test will be used to compare concentrations in background to the concentrations observed on the home site. The WRS test is a two-sample test that compares the distribution of a set of measurements in a survey unit to that of a set of measurements in a reference area. The test is performed by adding the value of the $DCGL_W$ to each measurement in the reference area. The combined set of survey unit data and adjusted reference area data are listed, or ranked, in increasing numerical order. If the ranks of the adjusted reference site measurements are significantly higher than the ranks of the survey unit measurements, the survey unit demonstrates compliance with the release criterion.

3.4 HOME-SITE SCREENING PROTOCOL

This section describes the screening protocol that will be conducted on all home sites within the defined area of interest. The results of this screening will be used to identify which home-sites do not require further action and which home-sites require an extent of contamination survey. The procedures discussed below detail the scanning and stationary readings using gamma sensitive field instruments methodologies for this part of the UHSA.

Scanning is an evaluation technique performed while moving a radiation detector over a surface at a specified speed and distance above the surface. Count rate data is routinely collected at 2 second intervals, numerically converted to counts per minute (cpm), and often tagged with GPS coordinates using a global positioning system. It would be desirable to use gamma scanning data to identify which home sites could be omitted from further consideration. Unfortunately, due to the very low $DCGL_W$, this technique does not appear to have the required sensitivity to make this determination. As an example, MARSSIM table 6.7 (included in this document as Table 7.) provides the scanning sensitivity for Ra-226 using a 2x2 Sodium Iodide (NaI) detector at 2.8 pCi/g, assuming a background count rate of 10,000 cpm. When scanning, MARSSIM recommends a minimum detectable concentration (MDC) of 50% of the $DCGL_W$. Since the $DCGL_W$ for Ra-226 is 2.5 pCi/g above background, the desired sensitivity is 1.25 pCi/g above background. Assuming a background concentration of 1.0 pCi/g, the desired scanning sensitivity is 2.25 pCi/g inclusive of background., which is less than the 2.8 pCi/g sensitivity for this instrument listed in MARSSIM. Gamma scanning will be performed over 100% of the home site outside area to identify localized spots of contamination which are above the $DCGL_W$. Scanning data will be used to estimate the area and Ra-226 concentration in these localized areas of elevated contamination.

Another evaluation technique which is slower, but can achieve lower detection limits, is to collect stationary gamma readings above a fixed point. The count rate collected by this technique can be used to estimate the soil concentration within a reasonable field-of-view of the instrument, based upon both a calculated and an empirically-derived correlation. This technique is not as accurate as actual soil sampling and analysis in a laboratory, but is sufficient to meet the goals of this protocol. Stationary, 1-minute gamma readings will be collected at an 18 inch elevation above the soil surface at defined intervals across the home site. The minimum number of stationary readings will be taken from MARSSIM Table 5.3, plus 20%. MARSSIM Table 5.3 is included in this document as Table 6. The parameters that impact the calculation of the minimum number of measurements are the average concentration of contamination, the variability of the contamination, and the allowable type I and II decision errors. The first two parameters will be based upon scanning survey data, and the type I and II decision errors will be set at 0.05. The minimum number of measurements required to assess a home-site cannot be calculated without site-specific data, but for the typical residence 15 to 20 stationary readings will be sufficient to meet MARSSIM standards.

Stationary in-situ measurements will have a sensitivity of at least 2 pCi/g, inclusive of background for Ra-226, assuming an instrument background of 10,000 cpm. This estimate is calculated by the following analysis. Using Microshield® gamma ray shielding and dose assessment software (Grove, 2008), the exposure rate above an infinite plane of Ra-226 at 2.0 pCi/g was calculated to be 3.9 microRoentgens per hour (μR/h). From table 6.7 in MARSSIM, the response factor for a 2X2 NaI detector exposed to Ra-226 is 760 cpm/μR/h. Therefore, the detector would have a reading of 2934 cpm, above background. The minimum sensitivity of the detector can be calculated from the following formula from MARSSIM section 6.7.1:

$$MDC= (3+4.65(C_b)^{0.5})/ kT$$

Where C_b = background counts, assumed to 10,000 counts in 1 minute

T= background or sample count time, assumed to be 1 minute and

k= units conversion factor, in this situation equal to 1

In this case, the MDC calculates to 468 counts, which is well below the calculated response of 2934 counts resulting from exposure to a Ra-226 concentration of 2 pCi/g.

These calculations should be conducted by a qualified and experienced individual such as a Certified Health Physicist. These calculated results can be verified by empirical measurements described in section 3.5 below.

Table 6
Values of N/2 for Use with the Wilcoxon Rank Sum Test

	α=0.01					α=0.025					α=0.05					α=0.10					α=0.25				
	β					β					β					β					β				
Δ/σ	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25	0.01	0.025	0.05	0.1	0.25
0.1	5452	4627	3972	3278	2268	4627	3870	3273	2646	1748	3972	3273	2726	2157	1355	3278	2646	2157	1655	964	2268	1748	1355	964	459
0.2	1370	1163	998	824	570	1163	973	823	665	440	998	823	685	542	341	824	665	542	416	243	570	440	341	243	116
0.3	614	521	448	370	256	521	436	369	298	197	448	369	307	243	153	370	298	243	187	109	256	197	153	109	52
0.4	350	350	255	211	146	297	248	210	170	112	255	210	175	139	87	211	170	139	106	62	146	112	87	62	30
0.5	227	193	166	137	95	193	162	137	111	73	166	137	114	90	57	137	111	90	69	41	95	73	57	41	20
0.6	161	137	117	97	67	137	114	97	78	52	117	97	81	64	40	97	78	64	49	29	67	52	40	29	14
0.7	121	103	88	73	51	103	86	73	59	39	88	73	61	48	30	73	59	48	37	22	51	39	30	22	11
0.8	95	81	69	57	40	81	68	57	46	31	69	57	48	38	24	57	46	38	29	17	40	31	24	17	8
0.9	77	66	56	47	32	66	55	46	38	25	56	46	39	31	20	47	38	31	24	14	32	25	20	14	7
1	64	55	47	39	27	55	46	39	32	21	47	39	32	26	16	39	32	26	20	12	27	21	16	12	6
1.1	55	47	40	33	23	47	39	33	27	18	40	33	28	22	14	33	27	22	17	10	23	18	14	10	5
1.2	48	41	35	29	20	41	34	29	24	16	35	29	24	19	12	29	24	19	15	9	20	16	12	9	4
1.3	43	36	31	26	18	36	30	26	21	14	31	26	22	17	11	26	21	17	13	8	18	14	11	8	4
1.4	38	32	28	23	16	32	27	23	19	13	28	23	19	15	10	23	19	15	12	7	16	13	10	7	4
1.5	35	30	25	21	15	30	25	21	17	11	25	21	18	14	9	21	17	14	11	7	15	11	9	7	3
1.6	32	27	23	19	14	27	23	19	16	11	23	19	16	13	8	19	16	13	10	6	14	11	8	6	3
1.7	30	25	22	18	13	25	21	18	15	10	22	18	15	12	8	18	15	12	9	6	13	10	8	6	3
1.8	28	24	20	17	12	24	20	17	14	9	20	17	14	11	7	17	14	11	9	5	12	9	7	5	3
1.9	26	22	19	16	11	22	19	16	13	9	19	16	13	11	7	16	13	11	8	5	11	9	7	5	3
2.0	25	21	18	15	11	21	18	15	12	8	18	15	13	10	7	15	12	10	8	5	11	8	7	5	3
2.25	22	19	16	14	10	19	16	14	11	8	16	14	11	9	6	14	11	9	7	4	10	8	6	4	2
2.5	21	18	15	13	9	18	15	13	10	7	15	13	11	9	6	13	10	9	7	4	9	7	6	4	2
2.75	20	17	15	12	9	17	14	12	10	7	15	12	10	8	5	12	10	8	6	4	9	7	5	4	2
3.0	19	16	14	12	8	16	14	12	10	6	14	12	10	8	5	12	10	8	6	4	8	6	5	4	2
3.5	18	16	13	11	8	16	13	11	9	6	13	11	9	8	5	11	9	8	6	4	8	6	5	4	2
4.0	18	15	13	11	8	15	13	11	9	6	13	11	9	7	5	11	9	7	6	4	8	6	5	4	2

From MARSSIM, Table 5.3

Table 7
NaI Scintillation Detector Scan MDCs for Common Radiological Contaminants

Radionuclide/Radioactive Material	1.25 inch by 1.5 inch NaI Detector		2 inch by 2 inch NaI Detector	
	Scan MDC (Bq/kg)	Weighted cpm/μR/h	Scan MDC (Bq/kg)	Weighted cpm/μR/h
Am-241	1,650	5,830	1,170	13,000
Co-60	215	160	126	430
Cs137	385	350	237	900
Th-230	111,000	43,000	78,400	9,580
Ra-226 (in equilibrium with progeny)	167	300	104	760
Th-232 decay series (Sum of all radionuclides in the thorium decay series)	1,050	340	677	830
Th-232 decay series (In equilibrium with progeny in decay series)	104	340	66.6	830
Depleted Uranium[a] (0.34% U-235)	2,980	1,680	2,070	3,790
Natural Uranium[a]	4,260	1,770	2,960	3,990
3% Enriched Uranium[a]	5,070	2,010	3,540	4,520
20% Enriched Uranium[a]	5,620	2,210	3,960	4,920
50% Enriched Uranium[a]	6,220	2,240	4,370	5,010
75% Enriched Uranium[a]	6,960	2,250	4,880	5,030

[a] Scan MDC for uranium includes sum of U-238, U-235, and U-234

From MARSSIM Table 6.7

3.5 EMPIRICAL MEASUREMENT VERIFICATION

The U.S. Department of Energy (DOE) maintains radiation instrument calibration facilities in Grand Junction, Colorado that will be helpful to demonstrate the sensitivity and validity of the protocol. While these facilities were originally developed to calibrate gamma measuring instruments used in uranium exploration, they are also suitable for calibration of instruments used for remedial action measurements, specifically in-situ assays for natural radionuclides. These facilities were constructed by enriching a concrete mix with uranium ore, monzanite sand, and/or orthoclase sand.

The facilities most applicable to the UHSA protocol are the large area pads, located at the municipal airport in Grand Junction. These concrete pads measure 30 feet by 40 feet by 1.5 feet thick, and are therefore very representative of a uniform plane of contaminated soil. The concentrations of Ra-226, thorium-232 (Th-232), and potassium-40 (K-40) in each of the five calibration pads are provided in the Table 8.

Table 8
Calibration Pad Concentrations

Pad Designation	Concentration (pCi/g)[a]		
	Ra-226	**Th-232**	**K-40**
W1	0.82 ± 1.02	0.67 ± 0.10	12.67 ± 0.72
W2	1.92 ± 1.54	0.87 ± 0.12	45.58 ± 1.82
W3	1.70 ± 1.38	4.92 ± 0.26	17.07 ± 0.82
W4	12.07 ± 5.64	1.04 ± 0.12	17.56 ± .098
W5	8.36 ± 3.52	1.91 ± 0.16	34.68 ± 1.46

Note: [a] Uncertainties are 95 percent confidence level.

Empirical verification of the field instruments by using these calibration facilities would enhance the validity of the field measurements in the UHSA.

4. EXTENT OF CONTAMINATION

This section provides a detailed discussion of the science and assumptions made in association with the development of the procedures for the Extent of Contamination survey. The UHSA protocol calls for the implementation of these procedures on all home-sites which have radiological contamination in excess of the acceptable exposure values discussed in Section 3 of this protocol. These procedures are equivalent to the MARSSIM Characterization Survey. The results of this survey will be utilized by the EPA On-Scene Coordinator (OSC) to determine if a removal action on an individual home- site is warranted.

4.1 SOIL SAMPLING

The primary decision method to determine if a home site requires further evaluation will be based on in situ gamma measurements, both scanning and stationary. However, if in-situ gamma measurements indicate that the home site should be further evaluated, soil samples will be collected according to MARSSIM protocol. Since these samples will be collected to define the extent of contamination, the location and number of samples to be collected will be at the discretion of the sampling team, in consultation with the CHP, and under the direction of the EPA OSC. For estimation purposes, it is assumed that approximately 5 soil samples will be collected. Soil samples will be collected from the top 15 centimeters (cm) of soil surface and submitted to a qualified radiochemistry laboratory for gamma spectrometry analysis.

4.2 INDOOR SURVEYS

4.2.1 Gamma Exposure Rate

Based on data presented in Table 2, the dose rate from direct exposure to 2.5 pCi/g of Ra-226 is 13.4 mrem/year, assuming an occupancy factor of 4,380 hours/year indoors and 2,190 hours/year outdoors. Using Microshield® software, the exposure rate at 1 meter above an infinite plane of Ra-226 at 2.5 pCi/g is 4.8 μR/h, or converting to dose rate 3.1 μrem/h. The total dose received outdoors is then 3.1 μrem/h x 2190 hours/year or 6.8 mrem/yr. The remainder of the dose (13.4-6.8), or 6.6 mrem/yr is received indoors over a period of 4380 hours. The indoor dose rate is then 1.6 μrem/h, or converting to exposure rate, 2.5 μR/h. Therefore, if the outside soil is contaminated to a concentration equal to the $DCGL_W$ of 2.5 pCi/g, the allowable exposure rate indoors is 2.5 μR/h.

However, if there is no activity above background outside, all of the dose is received indoors. Using the primary criterion of 15 mrem/year (15,000 μrem/yr), and assuming an indoor residency fraction of 50%, or 4380 hours/year, the average dose rate within any occupied or inhabitable building will be limited to 3.4 μrem/h above background (or converted to exposure rate of 5.3 μR/hour above background). These limits can be compared to the Uranium Mill Tailings Radiation Control Act (UMTRCA) standard of 20 uR/h for indoor spaces. Note, the exposure rate will be the average exposure rate across all livable rooms within the structure, and will be measured using a Pressurized Ionization Chamber (PIC) located in the center of each room. A 2x2 NaI detector will be cross calibrated to the PIC in the home and used to survey for small areas of elevated count rate. The location of any anomalous count rates indicating an exposure rate greater than 2.5 μR/h will be recorded, along with the estimated area of the elevated reading and the maximum exposure rate. If localized areas of elevated gamma exposure are detected, a 100 cm^2 wipe of the area will be collected and the analytical results compared to the 20 dpm/100 cm^2 removable release standard for Ra-226 in NRC Regulatory Guide 1.86.

4.2.2 Indoor Radon Concentration

The criteria to be applied will be the EPA standard of 4 picocuries per Liter (pCi/L). A short-term test of at least 2 days duration will be conducted using either a charcoal canister, alpha track, or other suitable technique to determine the concentration of Rn-222 for that short period. The detector will be placed in the lowest lived-in level of the structure, and the owner will be instructed to keep outside doors and windows closed during the test and for at least 12 hours before initiating the test.

4.3 DATA INTERPRETATION.

Data collected from each home-site will be compared to two primary criteria; 1) does the TEDE excluding the contribution from radon progeny, exceed 15 mrem/year, or 2) does the Rn-222 concentration in the dwelling exceed 4 pCi/l. If either criterion is exceeded, the home-site would be considered for a Removal Action.

The radon criterion is the more straightforward to assess. If the Rn-222 concentration exceeds 4 pCi/l, EPA recommends either a second short-term test, or a long-term (90 days) test to verify the measurement. If verification confirms the presence of elevated Rn-222, there are numerous abatement techniques that can be used to reduce the concentration. For example, radon from soil gas is the primary cause of elevated radon. Sealing cracks or gaps in floors, walls, construction joints, and service pipes may reduce the influx of radon into the home. Another source of indoor radon is from well water. Point of treatment can effectively remove radon from the home water supply before it enters the home. A vent pipe system and fan, also known as a soil suction radon reduction system, pulls radon from beneath the structure and vents it to the outside.

Evaluation of site data to the TEDE criterion requires that a qualified health physicist review all of the site data and compare the actual site conditions to the assumptions that were used in developing the $DCGL_W$ using RESRAD. If actual site conditions are materially different than those assumed in RESRAD, a revised $DCGL_W$ will be calculated to which the site will be compared. Assuming actual site conditions are not materially different, the health physicist will estimate the TEDE to the resident based upon the average Ra-226 soil concentration outdoors, the summation of the contribution from localized elevated concentrations (hot spots) of Ra-226 outdoors, the external exposure rate indoors, and any other contributors to the TEDE which are identified during the survey. If the TEDE exceeds 15 mrem/year, the health physicist will meet with the EPA OSC to recommend abatement or mitigating techniques which could reduce the TEDE to an acceptable level. Some examples of techniques that can be used during a removal action include the excavation of localized hot spots of elevated activity in the soil and the removal of contaminated building materials used in the home construction.

Home-sites that have a TEDE above background but below 15 mrem/yr will be referred to the EPA Remedial Program and the NMED for any further actions deemed necessary.

5. REFERENCES

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APPENDIX 1

Printout of the RESRAD Run Using Default Input Parameters

APPENDIX 2

Printout of the RESRAD Run Using Site-Specific Input Parameters